SUMMARY REPORT ON

EVALUATION OF SITE-SPECIFIC RISK ASSESSMENT FOR CONTAMINATED LANDS

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1.0 INTRODUCTION

This document is a condensation of a more detailed report on two-phased study conducted for the Canada Mortgage and Housing Corporation (CMHC) to examine the practices and variability amongst practitioners of contaminated sites risk assessment in Canada. Golder Associates Ltd. (Golder) was retained by CMHC to design and conduct both phases of the study. Phase I consisted of a survey of practitioners in the private and regulatory sectors and Phase II consisted of a round robin study. The round robin study assessed the variability in risk estimates among a group of independent risk assessment teams which addressed the same hypothetical case study.

From a regulatory perspective, contaminated sites have traditionally been scrutinized using generic soil criteria to determine the acceptability of the soils. However, in response to the National Contaminated Sites Remediation Program, there is a growing trend in Canada to employ a risk assessment/risk management approach as an alternative to soil quality criteria. Further, in some provinces (e.g., BC) new soil quality criteria have been developed using risk-based principles that reflect specific land uses.

Risk assessment is the tool or process whereby insight is gained respecting human health risks and is distinct from risk *management*. This insight is communicated by the risk assessor to those involved in the risk management decision and, together with other considerations (e.g., local regulatory policies. stakeholder input, etc.), options are weighed and a decision rendered on the scope of remedial actions that are appropriate for the site.

Uncertainty in risk assessments has important ramifications on land value, business decisions and expenditures associated with remediation of the site. For example, a site may be considered to present acceptable health risks following assessment by one team, while a similar site/circumstances elsewhere in Canada is concluded to have unacceptable health risks by a different team. In reality the two sites may not differ substantially, yet there is potential for significantly different remedial actions and expenditures.

As the number of risk assessment/risk management projects is increasing together with professional practitioners, it is of interest to examine the variability amongst practitioners and gain insight as to what the major determinants are of the variability. This understanding could then assist in optimizing both the discipline and risk management

process in Canada. The present study was designed to explore these issues by employing a round robin risk assessment of a hypothetical case study of a contaminated site.

2.0 METHODOLOGY

2.1 Overview of Case Study

The purpose of the round robin study was to assess the degree of variability in risk estimates among participants, and analyze the sources of variability and uncertainty. To this end, the case study employed in this round robin was hypothetical and not designed to have any "correct" answer.

The hypothetical case study consisted of a residential housing development proposed on former industrial lands and in this respect is reflective of a "brownfields development". The developer and regulators have hired consultants (i.e., the round robin participants) to assess the potential human health risks to future residents. Participants were advised that potential risks to workers was not part of the present scope of work. Additionally, participants' efforts were constrained to eight working days to help standardize efforts among participants and also reflect the situation where a land developers requires a rapid assessment to facilitate business decisions. It was anticipated this case study and level of effort would require a *screening level* risk assessment rather than a highly detailed or *definitive* risk assessment.

The site was located on former industrial lands occupied by several different industries over the past 60-70 years. The site was located in a suburban area, was approximately 8 hectares in size and had been cleared of buildings and other structures. It was rectangular in shape, bounded on all four sides by paved roads, and adjacent properties were commercially developed. The proposed development was a suburban residential community consisting of approximately 60 single family dwellings on lots 35x1 10ft (10.7x33.5 m). Standard dwellings were to be two stories (1 8 0 0 f t 176 m') built on a non-structural concrete slab (0. lm thickness), with a full height basement, two-car garage, and forced air heating.

Several metals (cadmium, copper, lead, and zinc), benzene, and vinyl chloride were detected on the site. Elevated cadmium, copper, lead and zinc were measured in surface soils, elevated zinc and benzene in subsurface soils (3 .O-3.5 m depth), and vinyl chloride in

groundwater. Figure 1 provides a schematic summary of the hypothetical dwelling, soil horizons and contaminant distribution. Further details of the case study are provided in the final report which contains the documentation distributed to the participants.

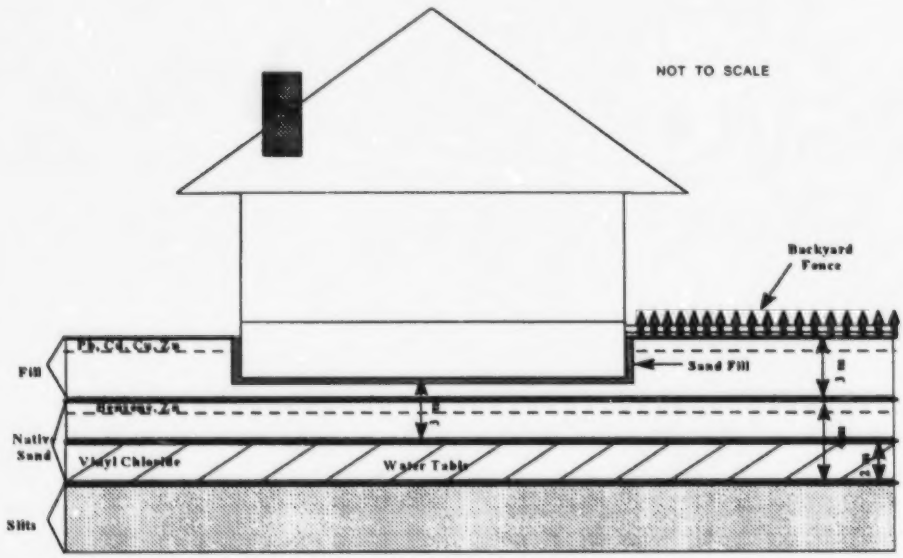

Figure 1
Building and Site Characteristics

In order to provide sufficient information for the data analysis phase and to reduce bias in the results, the case study was designed and implemented in the following manner:

1. All participants were given the same case study and instructions.

2. The case study provided both descriptive and quantitative details of the site and proposed residential development. A core set of raw data relevant to the site was provided for participants to analyze as they considered appropriate. To the extent possible, the round robin was designed to introduce "real world" variability for participants to deal with accordingly.

3. The participants were instructed to focus their efforts on numerical risk calculations rather than other non-quantitative information. Nevertheless, the

participants were given the opportunity to provide comments on methods to further refine risk calculations, mitigative measures, and other recommendations.

4 In order to minimize potential bias in the results, an attempt was made to help ensure that the level of effort was consistent amongst the various practitioners. Participants were instructed to perform a "preliminary risk assessment" with limited time and resources to allow developers to evaluate options at an early stage of the project. Participants were allocated a fixed sum of money and approximately 8 days (whichever was least constraining) to analyze the case study and provide numerical risk estimates for each exposure scenario identified by the participants, and rationale and/or numerical assumptions supporting the calculation of the risk estimates.

5. Pre-formatted generic reporting forms were provided to ensure that the information required by Golder/CMHC for the data analysis phase was received. These forms were designed to facilitate the documentation of risk estimates, computational methods, and numerical assumptions.

6. To foster real world regional variability into the study, the participants were instructed to abide with the relevant polices of their home province, and apply appropriate criteria, guidelines, and methodologies.

7. CMHC and Golder were available for limited consultation to clarify ambiguities and/or provide sources for further information. However, technical guidance was not provided to any of the participants.

8. Although Golder was also a participant in the risk assessment, the case study was performed "blind" by personnel not involved in the overall project. No technical assistance or other information which could compromise the study were provided to individuals completing the risk assessment.

2.2 Selection of Participants

A total of ten participants were originally selected to participate in the round robin risk assessment. One participant withdrew and, therefore, only nine participants comprised the final group. The participants were selected based on geographic location (to ensure Canadian regional representation) and apparent risk assessment experience and capabilities as determined from the private sector survey (a summary of Phase I is provided in the final report).

The experience and technical capabilities of the various firms which participated in Phase I of the study were ranked based on scores corresponding to questionnaire results. The questionnaire generated qualitative information on in-house capabilities, level of experience in various types of risk assessment, and technical capabilities in exposure assessment modelling, toxicity assessment, risk characterization, and risk management. A total score was derived for each firm based on the results of specific questions that were considered most relevant. In order to incorporate variability into the round robin, participants with *varying* apparent capabilities were selected. Four participants with high scores were selected, three participants with medium scores were selected and two participants with slightly lower scores were selected. Firms with very low scores, reflecting minimal experience and/or capability, were not selected for participation. It is recognized that this selection process in itself may introduce some unknown bias to the study results, however it is believed to have been minimized by selecting a cross section of capabilities.

Broad regional representation was achieved, with representation from British Columbia, the prairie provinces, Quebec and the Maritimes. As this project does not purport to assess the acceptability of the participants' performance, all results are presented in a way to preserve participant anonymity (i.e., only numerical identifiers are used, e.g., Participant #1 , 2, 3,. 9).

2.3 Data Analysis

The data analysis was designed to explore the variation among participants and to identify which parameters most are responsible for this variability. To accomplish this a tiered approach was employed to systematically determine the sources of variability. The first level (Tier I) of analysis examined the sources of variability in risk estimates, the second level (Tier II) examined the sources of variability in dose rate estimates and the third level (Tier III) examined the sources of variability in predicted concentrations in exposure media (Figure 2). The analysis employed both qualitative and statistical descriptions of results. A more detailed description of the approach is provided in the final report.

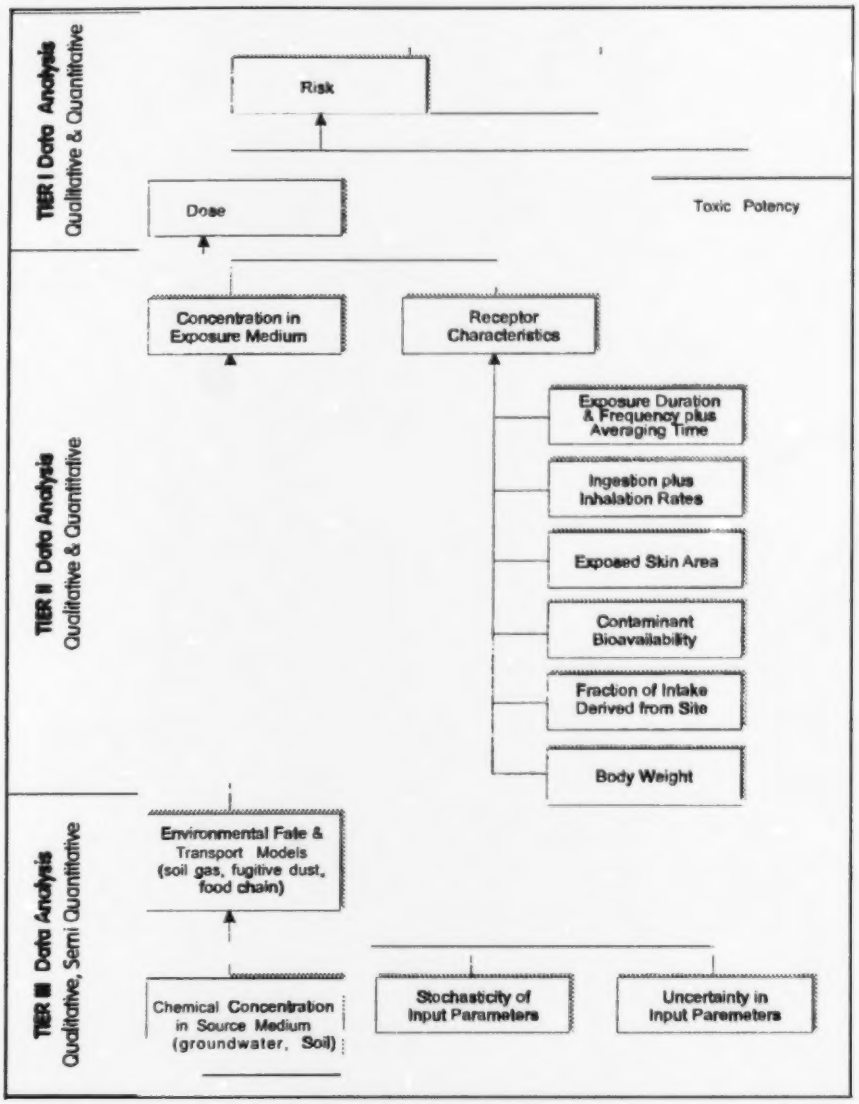

Figure 2

Influence Diagram for Contaminated Sites Health Risks

3.0 RESULTS AND DISCUSSION

3.1 Exposure Pathways Considered by Participants

The results indicate that the type and number of pathways addressed in the risk assessment varied between participants. For a particular contaminant source, some of the participants included a large number of exposure pathways while others included only a few (Table 1).

Table 1

Number of Participants Employing Specific Pathway/Contaminant/Receptor Combinations.

Exposure Pathway	COPC*	Mode of Toxicity	Adult Receptor	Child Receptor	Composite Receptor
Soil Ingestion	Zinc	non-carcinogenic	yes (n=5)	yes (n=6)	no (n=0)
	Copper	non-carcinogenic	yes (n=4)	yes (n=6)	no (n=0)
	Lead	non-carcinogenic	yes (n=4)	yes (n=7)	**no (n=0)**
	Lead	carcinogenic	no (n= 1)	no (n= 1)	110 (n=0)
	Cadmium	non-carcinogenic	yes (n=5)	yes (n=6)	no (n=O)
	Benzene	non-carcinogenic	no (n= 1)	no (n= 1)	110 (n=0)
	Benzene	carcinogenic	no (n=3)	no (n=2)	no (n=O)
Dermal Contact with Soil	Zinc	non-carcinogenic	yes (n=4)	yes (n=5)	no (n=O)
	Copper	non-carcinogenic	no (n=3)	yes (n=5)	no (n=0)
	Lead	non-carcinogenic	no (n=3)	yes (n=5)	**no (n=0)**
	Cadmium	non-carcinogenic	yes (n=4)	yes (n=5)	no (n=0)
	Benzene	carcinogenic	no (n=4)	no (n=2)	**no** (n=0)
	Benzene	non-carcinogenic	no (n=2)	110 (n=2)	no (n=0)
	Vinyl Chloride	cancer	no (n=l)	no (n=l)	no (n=0)
	Vinyl Chloride	non-carcinogenic	no (n=l)	no (n= 1)	no (n=0)
Inhalation of Dust	Zinc	non-carcinogenic	no (n=2)	yes (n=5)	**no** (n=0)
	Copper	non-carcinogenic	no (n=2)	yes (n=5)	**110 (n=0)**
	Lead	non-carcinogenic	no (n=2)	yes (n=5)	no (n=0)
	Cadmium	carcinogenic	yes (n=4)	yes (n=3)	no (n=0)
	Cadmium	non-carcinogenic	no (n= 1)	no **(n=4)**	**no** (n=0)
Ingestion of Produce	Zinc	non-carcinogenic	no (n= 1)	no (n=3)	no (n=0)
	Copper	non-carcinogenic	no (n= 1)	**110** (n=3)	no (n=0)
	Lead	non-carcinogenic	no (n= 1)	no (n=3)	**no** (n=0)
	Cadmium	non-carcinogenic	no (n= 1)	no (n=3)	no (n=0)
	Benzene	non-carcinogenic	no (n= 1)	**110 (n=** 1)	110 (n=0)
	Benzene	carcinogenic	no (n=2)	110 (n= 1)	no (n=O)
Inhalation of Volatiles (Indoor)	Benzene	carcinogenic	**no (n=4)**	**yes (n=4)**	**no (n=2)**
	Benzene	non-carcinogenic	no (n= 1)	no (n=2)	no (n=0)
	Vinyl Chloride	cancer	**110 (n=4)**	**110 (n=4)**	110 (n=1)
	Vinyl Chloride	non-carcinogenic	no (n= 1)	no (n= 1)	**110 (n=0)**
Inhalation of Volatiles (Outdoor)	Benzene	carcinogenic	yes **(n=5)**	**no (n=3)**	**no (n=** 1)
	Benzene	non-carcinogenic	no (n= 1)	**110 (n=2)**	**no (n=0)**
	Vinyl Chloride	carcinogenic	no (n=4)	no (n=3)	no (n=O)
	Vinyl Chloride	non-carcinogenic	no (n= 1)	**no (n=** 1)	**110 (n=0)**

Note:

*COPC - contaminant of potential concern

"yes" indicates that exposure pathway was included in statistical analyses.

"no" indicates that exposure pathway was not included in the statistical analyses.

The number of participants that included the specific exposure pathway is provided in the parentheses (i.e., (n=5)

Of the exposure pathways considered for trace metals in surface soils, oral ingestion was the most commonly included pathway. Ingestion of surface soils by children was included as an exposure pathway by six or seven of the nine participants (the actual number depended on the type of chemical) and ingestion by adults was considered by four or five participants. Fugitive dust inhalation and dermal contact with contaminated soil were the next most common pathways addressed. Ingestion of home produce contaminated by trace metals was considered by only three participants for children and one participant for adults. Considering that the calculations are complex, time constraints imposed to conduct the preliminary assessment may have limited the number of participants assessing this latter pathway.

For benzene contamination of subsurface soils and vinyl chloride contamination of groundwater considerable, variation was noted in the type and number of exposure pathways assessed by the participants. Indoor and/or outdoor exposure to vapours emanating from the soil were the most common pathways considered. Other exposure pathways considered by certain participants included ingestion of contaminated soil, dermal contact with chemical, and ingestion of home produce.

3.2 Modes of Toxic Action and Potency

The chemicals were either assumed to behave as non-carcinogens (threshold), genotoxic carcinogens (non-threshold), or both (Table 1). All of the participants considered zinc, copper, and lead as threshold toxicants while one of the participants considered lead to also behave as a non-threshold carcinogen. The classification of lead as a non-threshold carcinogen reflects the position held by the US EPA that lead is a probable carcinogen, although this is not a standard view held by Health Canada. For cadmium, participants considered the route of exposure in determining whether it was assumed as a non-carcinogen or carcinogen. For ingestion and dermal contact pathways, cadmium was assumed to behave as a threshold toxicant, while for the dust inhalation pathway, it was considered a carcinogen or assessed for both carcinogenic and non-carcinogenic endpoints (Table 1).

Toxic potency of chemicals is typically reflected by toxicity reference values (e.g., references doses or slope factors) obtained by the risk assessor from regulatory sources. However, the sources may vary, and in some instances the risk assessor may wish to

modify the reference value to reflect more recent information. In the present study, some toxicity reference values varied from less than ten-fold (e.g., cadmium) to five orders of magnitude (e.g., copper). This latter case is an exceptional example of inconsistencies in toxicological perspectives amongst assessors, and is undoubtedly an import contributor to variability in final risk estimates.

3.3 Variability in Non-Cancer Risk Estimates

Non-cancer risk estimates (i.e. hazard quotients) varied considerably between participants for similar exposure scenarios. Table 2 provides a summary of the range and ratio between the minimum and maximum risk estimates among participants, by contaminant and exposure pathway. For metals, similar patterns in dispersion of risk estimates emerged as a function of exposure pathway. As an illustrative example, Figure 3 provides the dispersion of risk estimates (hazard quotients) for zinc with regard for exposure pathway, receptor type and participant.

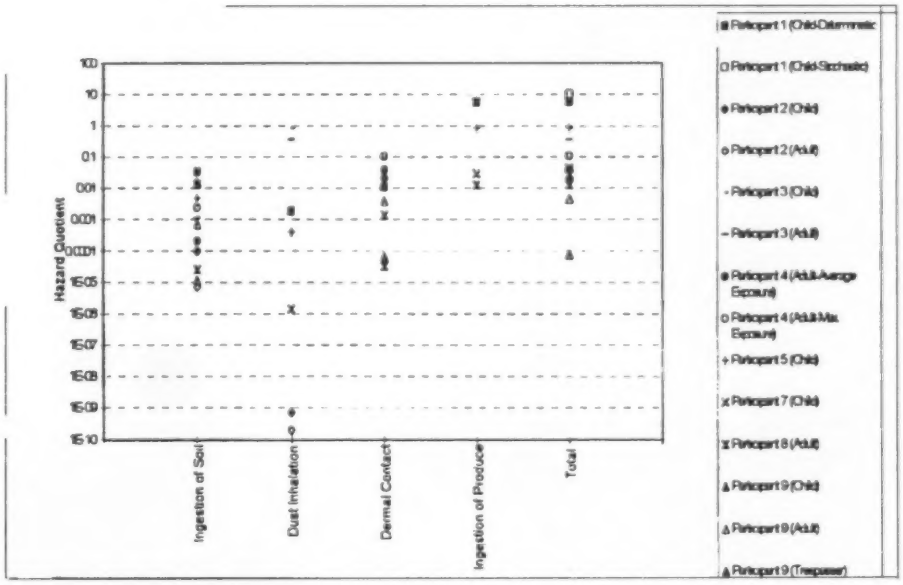

Figure 3
Non-Cancer Risks Associated with Zinc Exposure

Hazard quotients for *ingestion* of zinc in surface soils ranged from 7.0×10^{-6} to 3.3×10^{-2} (Table 2) which represents approximately four orders of magnitude difference between minimum and maximum values. It is important to note, however, that this range of difference encompasses consideration of both adult and child receptor; the difference would be smaller if the comparison was constrained to one receptor type (Figure 3). In general, the soil ingestion pathway yielded the least variation among participants. In contrast, hazard quotients for *inhalation* of fugitive dust particles containing zinc, ranged from 2.0 x 10"" to 8.3 x 10-l a difference spanning almost nine orders of magnitude. High levels of variability were also found for the other chemicals and exposure pathways. The greatest ranges in risk estimates were found for dust inhalation of copper, lead and zinc, with the ratio between maximum and minimum values exceeding one billion. Additional scatter plots for other contaminants and non-cancer health risks are provided in the main report.

Table 2

Summary of Non-Cancer Risks for Future Residents.

Values representing the minimum, maximum and ratio are based on consideration of both adult and child receptors

Exposure Pathway	COPC	Min	Max	Max:Min
Soil Ingestion	Cadmium	1.0E-04	6.8E-01	6.8E+03
	Copper	3.0E-05	1.1E+00	3.7E+04
	Lead	2.0E-03	1.4E+04	6.9E+06
	Zinc	7.0E-06	3.3E-02	4.7E+03
	Benzene[1]	0.0E+00	0.0E+00	-
Dermal Contact with Soil	Cadmium	5.8E-03	3.8E+00	6.5E+02
	Copper	1.0E-09	3.2E+02	3.2E+11
	Lead	1.6E-02	4.0E+01	2.5E+03
	Zinc	3.2E-05	1.0E-01	3.2E+03
	Benzene[1]	0.0E+00	1.3E-07	-
	Vinyl Choride	2.1E-03	3.5E-03	1.7E+00
Inhalation of Dust	Cadmium	5.8E-05	3.7E-01	6.4E+03
	Copper	1.0E-09	3.2E+02	3.2E+11
	Lead	2.0E-08	3.8E+02	1.9E+10
	Zinc	2.0E-10	8.3E-01	4.2E+09
Ingestion of Produce	Cadmium	1.1E-01	1.3E+01	1.1E+02
	Copper	3.9E-03	8.3E+00	2.1 E+03
	Lead	1.1E+00	5.8E+02	5.1 E+02
	Zinc	1.3E-02	5.6E+00	4.5 E+02
	Benzene[1]	0.0E+00	0.0E+00	-
Inhalation of Volatiles. Indoo	Benzene	2.9E-04	2.8E+01	9.8 E+04
	Vinyl Choride	2.2E-02	9.7 E-02	4.4E+_0.0
Inhalation of Volatiles. Outd	Benzene	1.2E-05	5.2E-02	4.3E+03
	Vinyl Choride	9.3E-04	1.7E-02	1.8E+01

[1] One of the participants estimated exposure concentrations of 0 mg/kg benzene, which explains the risk estimates of 0.

*Contaminant of potential concern

3.4 Variability in Cancer Risk Estimates

Incremental lifetime cancer risk (ILCR) estimates also varied considerably between participants (Table 2). For instance, cancer risk estimates for inhalation of dust containing cadmium ranged from 3 .0 x 10-1 to 3 .0 x 10^{-4}, risk estimates for indoor inhalation of vapours containing benzene ranged from 9.5 x 1 0^{9} to 3.5 x 1 0^{-2}, and risk estimates for indoor inhalation of vapours containing vinyl chloride ranged from 2.2 x 10^{9} to 2.4 x 10'". Figure 4 illustrates the variability in risk estimates for benzene; additional scatter plots for other contaminants are available in the main report.

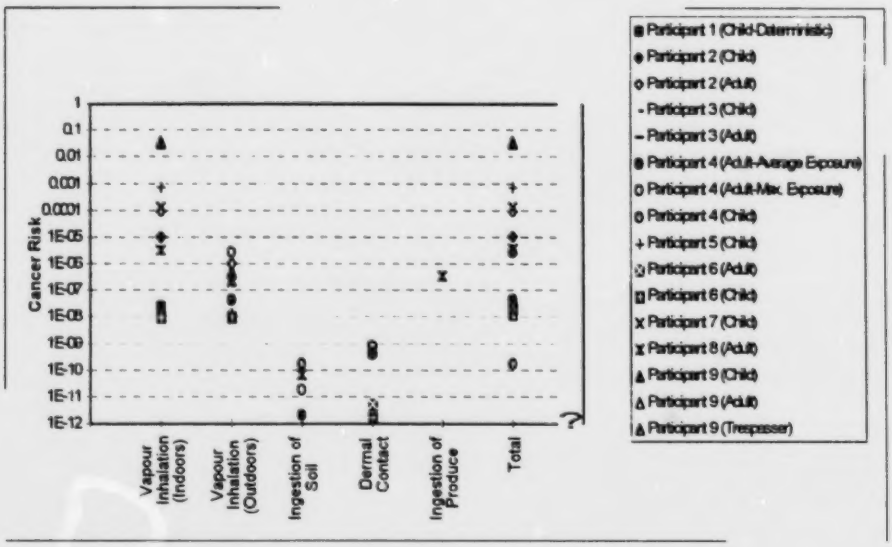

Figure 4
Cancer Risks Associated with Benzene Exposure

3.5 Apparent Acceptabilty of Calculated Health Risks

In light of the large differences in risk estimates among participants, hazard quotients and lifetime cancer risks were examined for their apparent acceptability. In the case of hazard quotients, a health risk was considered acceptable if it was less than unity (<1.0) and unacceptable if greater than unity (>1 .0), this being a commonly held regulatory/societal view. For lifetime cancer risks, exceedance of the probability of one in a million (1x10'") was considered unacceptable. Figures 5 and 6 summarize the distribution of acceptable

versus unacceptable health risks using the above criteria. The results vary from consensus on the unacceptability of health risk from lead, to essentially a split decision for some other contaminants (e.g., benzene, copper cadmium). It should be noted however, that these differences are not only a reflection of the variability of the participants, but are also a reflection of the contaminant levels selected for the case study. Higher or lower contaminant levels may yield greater or lessor amounts of agreement in the acceptability of health risks

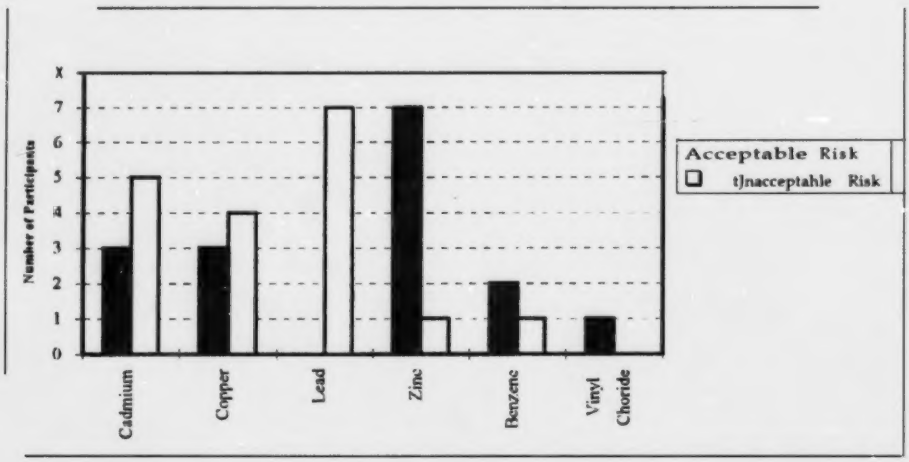

Figure 5
Acceptability of Total Risk (Hazard Index) for Non-Carcinogens
Graph displays number of participants concluding
acceptable or unacceptable risk for each chemical.

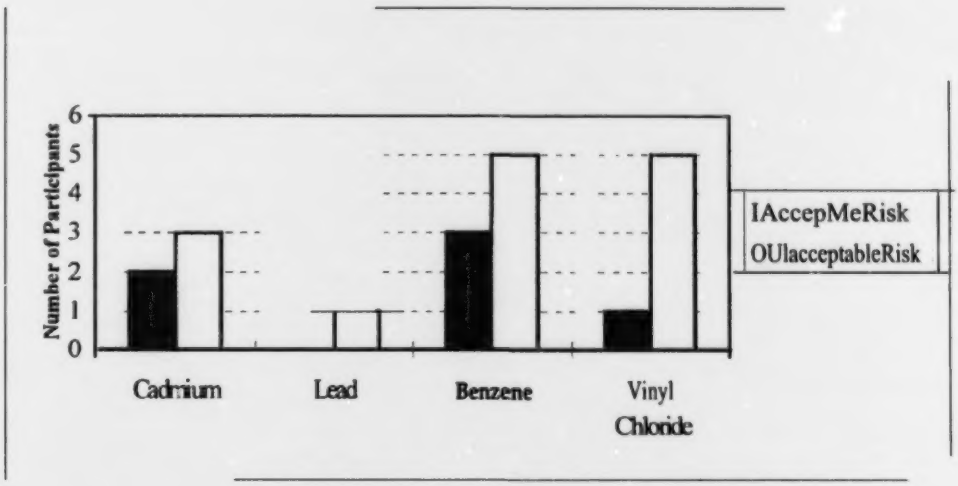

Figure 6
Acceptability of Total Risk for Carcinogens
Graph displays number of participants concluding acceptable or unacceptable risk for each chemical.

3.6 Sources of Variability in Risk Estimates

Variability in risk estimates can be caused by variability in the dose rates and variability in the toxicity reference values. Statistical methods determined that in general the largest proportion of the variability (in some cases virtually 100 %) was explained by the dose rate. This is, in part, intuitively predictable since many variables and assumptions are employed to estimate dose rates, while toxicity reference values are typically obtained from regulatory agencies and should, in theory vary less.

Dose rates were therefore examined to determine what variables contributed most to the variation in this parameter. As a collective group, receptor *characteristics (e.g.* ingestion rate, exposed dermal area, exposure frequency, body weight, etc.) accounted for 53-86 % and 80 -99 % of variation in dose rates of metals received via soil ingestion and dermal absorption, respectively. However, the estimated *exposure concentration* accounted for the majority (58-97 %) of variability observed in dose rates modeled via inhalation of fugitive dust. Similarly, the variability in dose rate for benzene via inhalation of contaminated indoor air was primarily explained by the predicted indoor air concentration.

The predicted concentration of benzene indoors ranged from 0.0000027 mg/m3 to 9.64 mg/mg3, this variability due mostly to the different residential contaminant transport models used.

In general, it appeared that the variability in dose rates derived via more complex pathways (e.g., indoor air or fugitive dust pathways) was more a function of the exposure concentration predicted by the fate and transport model, while variability in dose rates for the less complex pathways (soil ingestion and dermal absorption) was more a function of the receptor characteristics.

In light of the above observation, the use of complex transport models such as those used to predict indoor vapour concentrations from soil gas infiltration or generation of fugitive dust concentrations should be scrutinized carefully. Not only can these models be used with considerable differences in assumptions by the modeller, but the mere selection of one model versus another may lead to considerably different results due to model uncertainty. Further, this observation would argue for consideration of model validation and/or a good understanding of where the model is more, or less, conservative in nature. It would seem appropriate that some form of standardization for residential contaminant transport models be recognized.

Further analysis (using data for zinc/soil ingestion) suggest the *exposure frequency* and incidental soil *ingestion rate* were the primary determinants of the grouped receptor characteristics (82 and 17 % of explained variability, respectively). Additional analysis of variability associated with receptor characteristics or transport models was hindered by insufficient replication (some participants excluded some pathways from analysis) and covariance of some variables, The fact that several receptor characteristics covaried suggests some risk assessors were applying conservative assumptions to all the variables *collectively* rather than selectively applying conservative assumptions to only one or two variables. This "blanket conservatism" should be avoided because it propagates considerable uncertainty and lack of realism in the final risk estimate, and undoubtedly contributes to the large range in risk estimates previously described. Further details of this analysis are available in the main report.

4.0 RELEVANCE TO DECISION MAKING

Contaminated sites risk assessment is intended to be a tool by which to obtain insight on health risks for purposes of assisting in making decisions. The basic areas of decision making in this context are either risk management decisions (i.e., steps required to mitigate health risks), and business decisions (i.e., land purchases, remediation for elimination of liability, etc.). In both cases the relevant point is that expenditures/investments are being made, in part, on insight gained from health risk assessment. Understandably there is both a need and desire for expenditures and decisions to be justified.

This present study provides some interesting perspectives on how risk estimates may affect business decisions, and to a lesser extent risk management decision. In the first case, the wide variability in risk estimates, coupled with diversity of what is or is not an issue for consideration (e.g., inclusion versus exclusion of selected pathways), may give rise to very different perceptions about the liabilities intrinsic to a specific site. Thus, total risk estimated by one team may suggest health-related liabilities are virtually zero, while another team may conclude a need for closer examination. If liabilities are perceived to be virtually zero, this may support the purchase of property, or perhaps a decision to sell without further remediation. A more conservative estimate of risk may support the opposite decision.

While agreement amongst participants on acceptability versus unacceptability of risk estimates was relatively good in this study, the wide spread in risk estimates suggest disagreement is highly likely if the contaminant source concentrations are of a magnitude to create borderline concerns.

In the second case of decision making, risk management decisions, there is potential for a similar conundrum. However, it is imperative for risk managers to recognize the "weight-of-evidence" offered by screening risk estimates as developed in this Round Robin, versus the weight-of-evidence offered through *defeinitive* (i.e., detailed) risk assessment. As exemplified in the present study, screening risk estimates are "bounding estimates", designed to bound the reasonable upper limit of health risk. They are expected to be conservative (but not overly conservative) with the idea that even a borderline acceptance risk estimate is likely to be interpreted as acceptable owing to the inherent

conservatism. Conservative estimates which are clearly de *minimums (e.g.,* HQ < 0.01, or ILCR < 1E-7 are likely to be smaller in reality, and would not support the need for risk-reduction measures.

Where screening risk estimates suggest a substantial health hazard exists, the wide variability in results from this study would suggest risk management decisions not be made until more definitive computations are conducted.

This study provides a basis to benchmark the variability amongst risk assessors, under "screening risk assessment" conditions. The variability in this case is the product of differing views in applying conservatism in exposure assumptions, differences in analyzing raw contaminant data, differences in perceived importance of specific exposure pathways and differences in the use of contaminant transport models and their inherent uncertainty.

The degree to which definitive risk estimates would vary amongst the same participants cannot be derived from this study. However, in theory one would expect a convergence amongst assessors, as more definitive (realistic and/or site specific) exposure assumptions are factored into the assessment, with a concomitant reduction in the variability of conservatism employed. In the final analysis, all risk assessments, whether screening or definitive in nature, should include some level of uncertainty analysis to allow the reviewer to appreciate the level of conservatism and range over which other possible value of health risk may apply. To this end, it is recommended that all contaminated sites health risk estimates be expressed at least as a possible range of values (e.g., reasonable minimum, reasonable maximum) and preferably with some aspect of probability associated with the assumption employed (e.g., mean, made or probability distribution). This would foster a better understanding of the health risks for both risk assessors and risk managers, and better support consequent risk management decisions,

5.0 CONCLUSIONS

Several conclusions were derived from this study. However, it is important to re-emphasize the present study was conducted as a screening risk assessment, not a definitive risk assessment. For some of the conclusions it may be reasonable to speculate that the same would hold true for a definitive assessment, but this may not apply in all cases.

1. Fundamentally, the type and number of pathways included in the risk assessments varied between participants. For trace metals in surface soils, oral ingestion was the most commonly included pathway. Fugitive dust inhalation and consumption of domestically grown produce were included/excluded by various participants.

2. Highly divergent risk estimates were demonstrated for all contaminants and exposure pathways. While general agreement existed amongst the acceptability of the risks, the divergence suggest lack of agreement could prevail if soil contaminant concentrations were closer to critical levels.

3. The variability in risk estimates was primarily explained by variability in dose estimates. Thus, for improved conformity amongst assessors, both of these elements should be considered.

4. The variability in dose estimates via direct pathways (e.g., soil ingestion and dermal contact) were primarily explained by receptor characteristics. The variability in dose estimates for complex indirect pathways (e.g., dust inhalation and indoor gas inhalation) were primarily explained by model uncertainty, which affected the predicted exposure concentration.

5. Correlation amongst the various determinants of dose suggest assessors are applying conservatism to several variables. This suggests the need to re-visit the approach to applying conservatism, to avoid overly conservative risk assessments and uncertainty.

6. Models used to predict wind generated dust emissions are highly dependent on input parameters such as soil type, vegetative cover and size of the site. Therefore, it is important for screening-level risk assessments to use appropriate site-specific data.

7. Models used to predict soil gas fate and transport are highly dependent on the model assumptions, and site-specific parameters such as depth to contamination, soil properties (e.g., porosity, permeability and organic carbon fraction) and building characteristics (e.g., concrete cracks, drains and building underpressurization).

8. In light of items (6) and (7) above, it would be desirable to employ contaminant transport models which have been validated and/or develop a standardized yet reasonable approach to their implementation for risk assessment of contaminated lands.